

Marine mammals and conservation in the Antarctic marine system

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M. M. Bryden

Department of Veterinary Anatomy, University of Sydney, NSW 2006

The principal factor affecting the antarctic marine ecosystem in the last 70 years has been, undoubtedly, exploitation of the great whales. Five species of rorquals (Mysticeti: Balaenopteridae; see Fig. 1, front cover) are widely distributed and are sympatric in the Southern Ocean (Fig. 2) during the summer feeding phase of the annual cycle. They are the blue, fin, sei, humpback and minke whales. In the 60-year period 1925–26 to 1984–85, more than one million of these five species of whales were killed in the Southern Ocean, and more of some species of these southern rorquals (mainly humpback whales) were killed in lower latitudes during their winter breeding migrations.

In less than 50 years, the populations of blue, fin, sei and humpback whales were reduced by 90 per cent or more. It has been said that blue whales have been depleted to about 1 per cent of their pre-whaling numbers, but data are insufficient to substantiate such claims. We have some evidence that humpback whales, at least in some areas were depleted as severely as that. Minke whales were not killed during most of this period, as they were considered too small to sustain a viable industry. It was only near the end of the whaling period, when numbers of the large rorquals had been reduced so drastically, that some minke whales were taken.

The principal food item for all these species, as well as some species of seals, sea birds, fish, and larger invertebrates such as certain squid, is krill. The term "krill" is a Scandinavian word meaning "whale food", but in the antarctic context, krill and the genus *Euphausia* are virtually synonymous, because the huge swarms of organisms that comprise the food of rorquals and other krill predators are made up largely (over 90%) of the single species *Euphausia superba*.

There has been some argument about the relative importance of krill in the antarctic marine ecosystem, as research has revealed more details of the system. There is no doubt, however, that along with copepods, euphausiids are the dominant organisms in the

zooplankton of antarctic marine waters. Krill is still regarded as the key trophic intermediary between primary production and many higher vertebrate consumers in the Southern Ocean (Fig. 3). This view is supported strongly by the work of Rau *et al.* (1992), who demonstrated a similarity between the anticipated range of vertebrate dietary nitrogen 15, and nitrogen 15 content of antarctic krill.

In the Southern Ocean, krill (*Euphausia superba*), (Fig. 4, see colour section), forms huge swarms where phytoplankton blooms occur, especially near ocean upwellings. In coastal regions swarms of *Euphausia crystallorophias* occur. The major mammalian krill predators are the crabeater seals (*Lobodon carcinophagus*), of which there are approximately 15 million, and in some regions at least, antarctic fur seals (*Arctocephalus gazella*). See Figures 5 and 6 (see colour section).

Major shifts in the balance of the various Southern Ocean predators have occurred in recent years, probably as a direct result of the depletion of the great whales. Among the mammals there is good evidence that numbers of at least some rorquals, crabeater seals and antarctic fur seals increased dramatically from the 1950s to the 1980s. Allied to these shifts in relative abundance of krill predators, increases in the pregnancy rates of fin and sei whales, and a possible decrease in their age at sexual maturity, were observed. Age at sexual maturity of crabeater seals and possibly minke whales also appeared to have declined (Fig. 7), and there is some evidence that the present crabeater seal and minke whale population levels are significantly greater than those existing before intensive southern whaling began. Some increases in populations of krill predators have been dramatic. The Antarctic fur seal population at South Georgia showed a 14–17 per cent increase annually for several years. There may have been a levelling off of some of these population shifts in recent years.

In the early 1970s, concern was raised about the potential effects of exploitation of krill for human consumption. This enormous resource

was viewed as having the potential to overcome a perceived worldwide shortage of animal protein. Removal of large amounts of krill from antarctic waters, it was argued, may adversely affect the recovery of whale stocks. A krill fishery has been operating in antarctic waters for over 20 years. A total of more than 5 million tonnes of krill was harvested from 1973 to 1992 (see Fig. 8). While this catch has been limited, and is unlikely to increase significantly in the immediate future, future increase could be expected to have a major impact on the balance of species within the antarctic marine system.

Chittleborough (1984) estimated that in the undisturbed pre-whaling period, baleen whales consumed about 180 million tonnes of Antarctic krill per year. This is greater than the combined consumption by seals, birds and fish. The current depleted whale population consumes an estimated 40 million tonnes per year. This is about 80 times the 1982 maximum commercial catch of krill, and about eight times the total commercial krill catch over 20 years. If we take the simplest view, it means also that

approximately 140 million tonnes of Antarctic krill annually are available for consumption by predators in Antarctic waters that were not available before whaling began. Other species, particularly fin fish and squid, are harvested in significant numbers in some regions, particularly the southern Atlantic Ocean. These activities potentially can affect certain specific higher-level predators, but some of these harvested species are themselves predators on krill so their removal may remove some of the pressure from the mammalian krill predators.

In contrast to the apparently dramatic increases in populations of krill predators, in recent years there has been a decline in numbers of southern elephant seals in the Southern Ocean. Elephant seals are not predators of krill, but they do feed on species that are themselves dependent on krill (see Fig. 3). The decline has not been uniform — whereas elephant seal populations in the southern Pacific and Indian Ocean regions have declined by 50 per cent in the last 30 years or so, the southern Atlantic Ocean population has remained static over the same period.

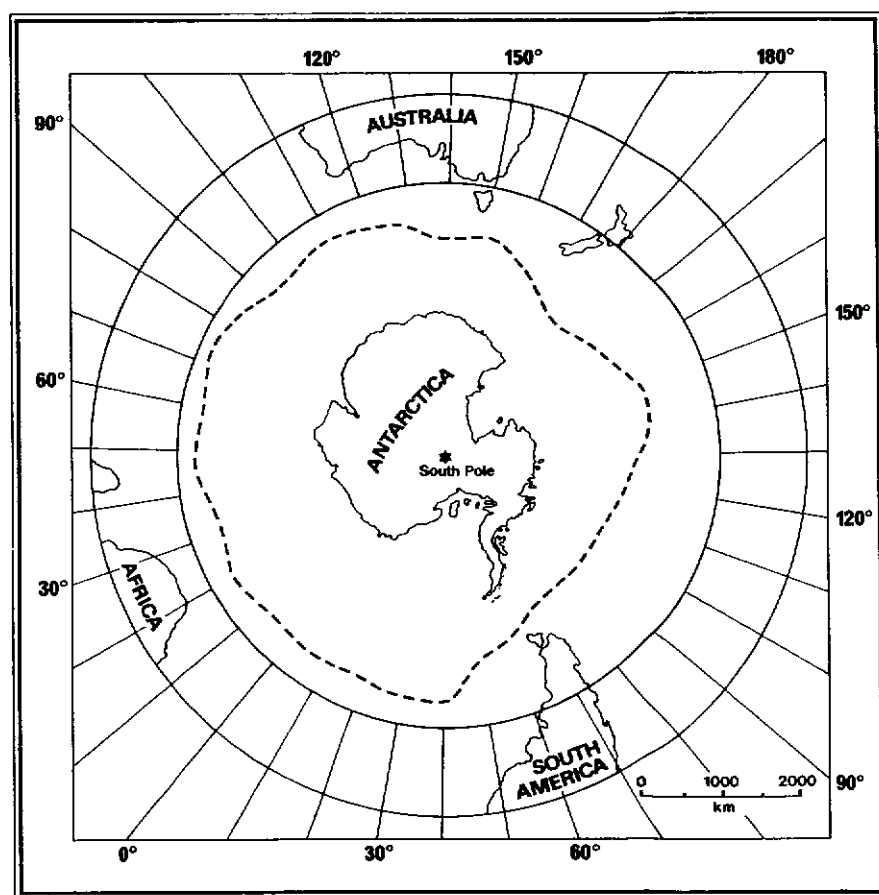


Fig. 2. The Southern Ocean extends from the shores of the Antarctic continent to latitude 40°S. Here the latter is shown as the circle passing through Bass Strait, New Zealand, the southern part of South America and to the south of southern Africa. The dashed line represents the Antarctic Polar Front (Antarctic Convergence).

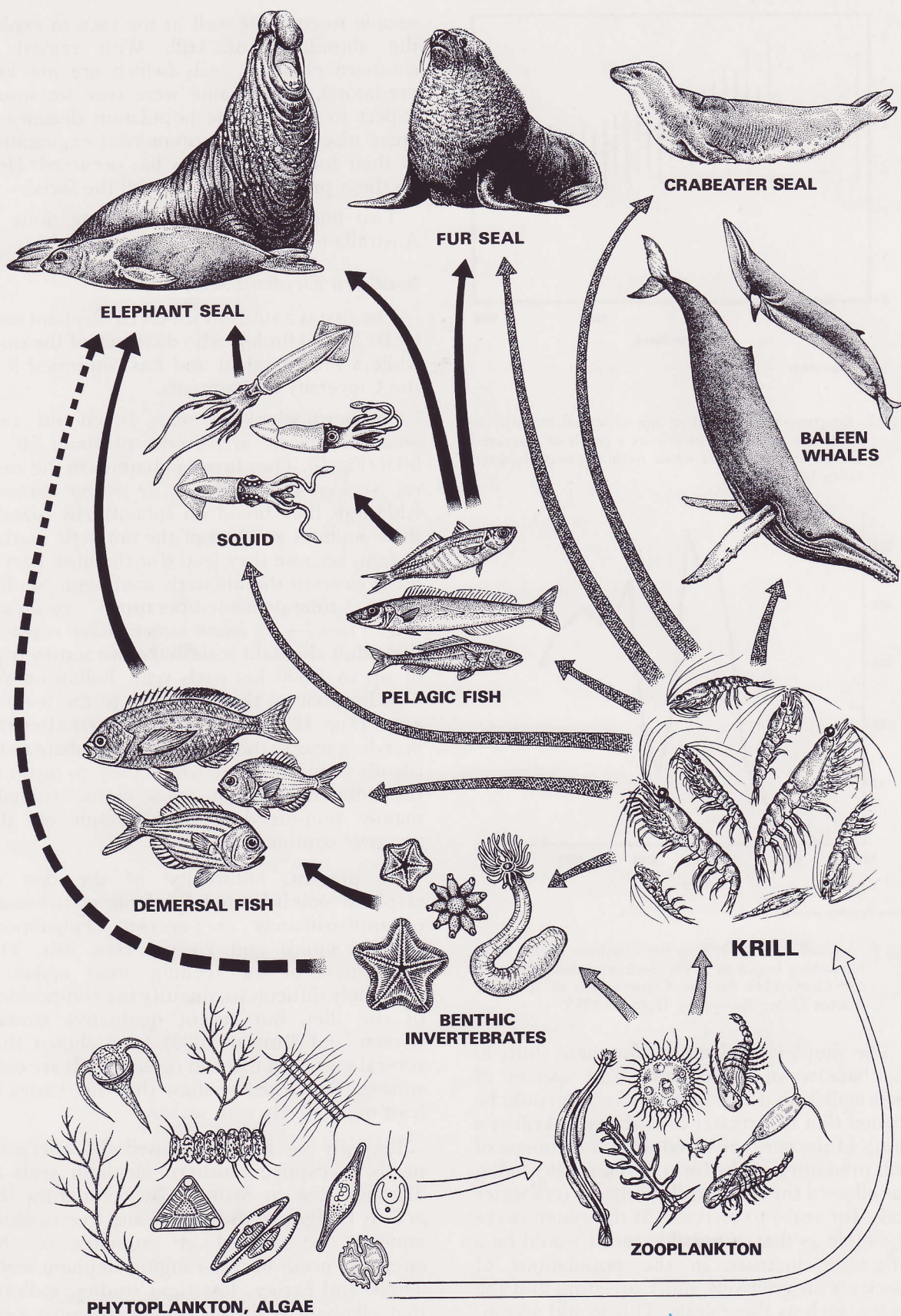
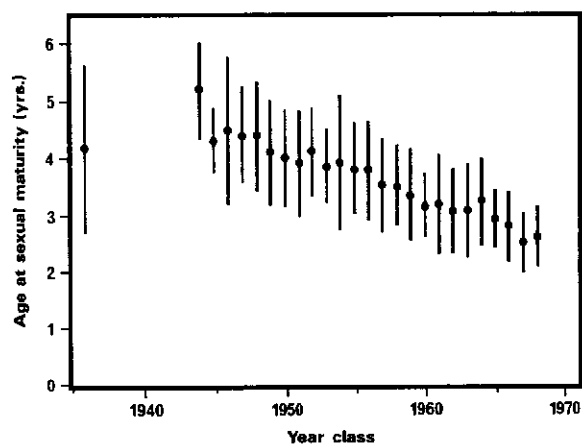
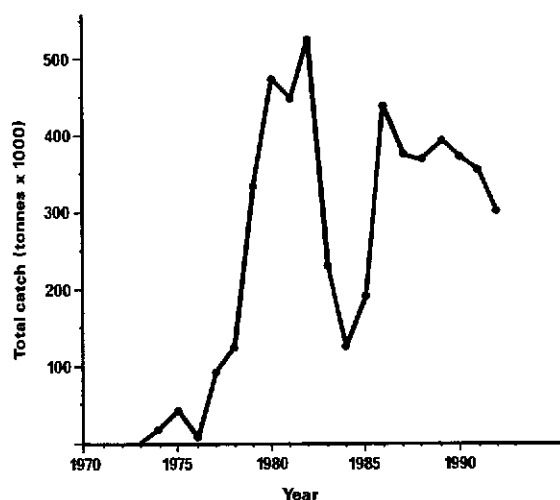


Fig. 3. Simplified depiction of the food web in the antarctic marine ecosystem. Mammalian predators of krill include the rorquals (baleen whales), crabeater seals and some antarctic fur seals. Elephant seals are not direct krill predators. Not shown are the sea birds, including penguins, some of which are major predators of krill.



From: Laws (1977)

Fig. 7. Progressive reduction in age of sexual maturity in crabeater seals, presumably as a result of increased food abundance after whale numbers were depleted (after Laws 1977).



From: CCAMLR records

Fig. 8. Annual catch of krill in the Southern Ocean since harvesting began in 1973. (Source of data: Office of the Convention for the Conservation of Antarctic Marine Living Resources, Hobart 1993.)

The simplest explanation for these shifts in the balance of populations and species of mammals is that it is food-derived. It could be argued that the greater availability of krill as a result of the very great reduction in biomass of krill predators, in the form of the great whales, has allowed the other krill predators (crabeater seals, fur seals) to increase. If the system were as simple as that, a possible result would be a long-term increase in the populations of species with relatively short breeding and life cycles, such as these seals. This would accompany a slower increase in numbers of rorquals, and possibly stabilization of populations at lower than pre-whaling levels, because they have a lower fecundity and therefore are

unable to compete well in the race to exploit the abundance of krill. With regard to southern elephant seals (which are not krill predators), if the same were true we would expect to observe the population declines in areas where greatest commercial exploitation of their food components has occurred. How do these proposals line up with the facts?

Two lines of research are being done in Australia to examine these proposals.

Southern Elephant Seals

The first is a study of southern elephant seals by Dr Mark Hindell, who did some of the work while a PhD. student and has continued it in the University of Tasmania.

Southern elephant seals breed on subantarctic islands, at latitudes of about 50° to 60°S (Fig. 9). They breed in harems in the austral spring (Fig. 10 — see colour section). Although they breed on subantarctic islands, these animals are part of the antarctic marine system, because they feed (for the most part at least) close to the antarctic continent. Studies using time-depth-temperature recorders (Fig. 11a-c — see colour section) have revealed that adult elephant seals make two return trips of up to 1 600 km each year. Following the breeding season they go south to the feeding areas (Fig. 12). About three months after the breeding season they return to the subantarctic islands to moult, after which they go again to the antarctic feeding areas. Some animals, mainly non-breeding bulls, moult on the antarctic continent itself.

At present, knowledge of the diet of elephant seals is limited. It is believed to consist of approximately 75 per cent cephalopods (mainly squid) and 25 per cent fish. The remoteness of the feeding areas makes it extremely difficult to quantify the composition of the diet, but recent qualitative studies (Green and Burton 1993) have shown that several species of fish and cephalopods are consumed. They further show that diet varies at least qualitatively with season.

Recently we have examined the energetic needs of captive southern elephant seals at Taronga Zoo in Sydney. By comparing the activity budgets of the captive and free-ranging animals, we arrived at estimates of the energetic needs of free-ranging elephant seals. These and earlier, less rigid studies, indicate that elephant seals are significant consumers within the antarctic marine system (Table 1). The elephant seal population in the southern Pacific Ocean sector declined at an annual rate of approximately 2 per cent for 20 years until

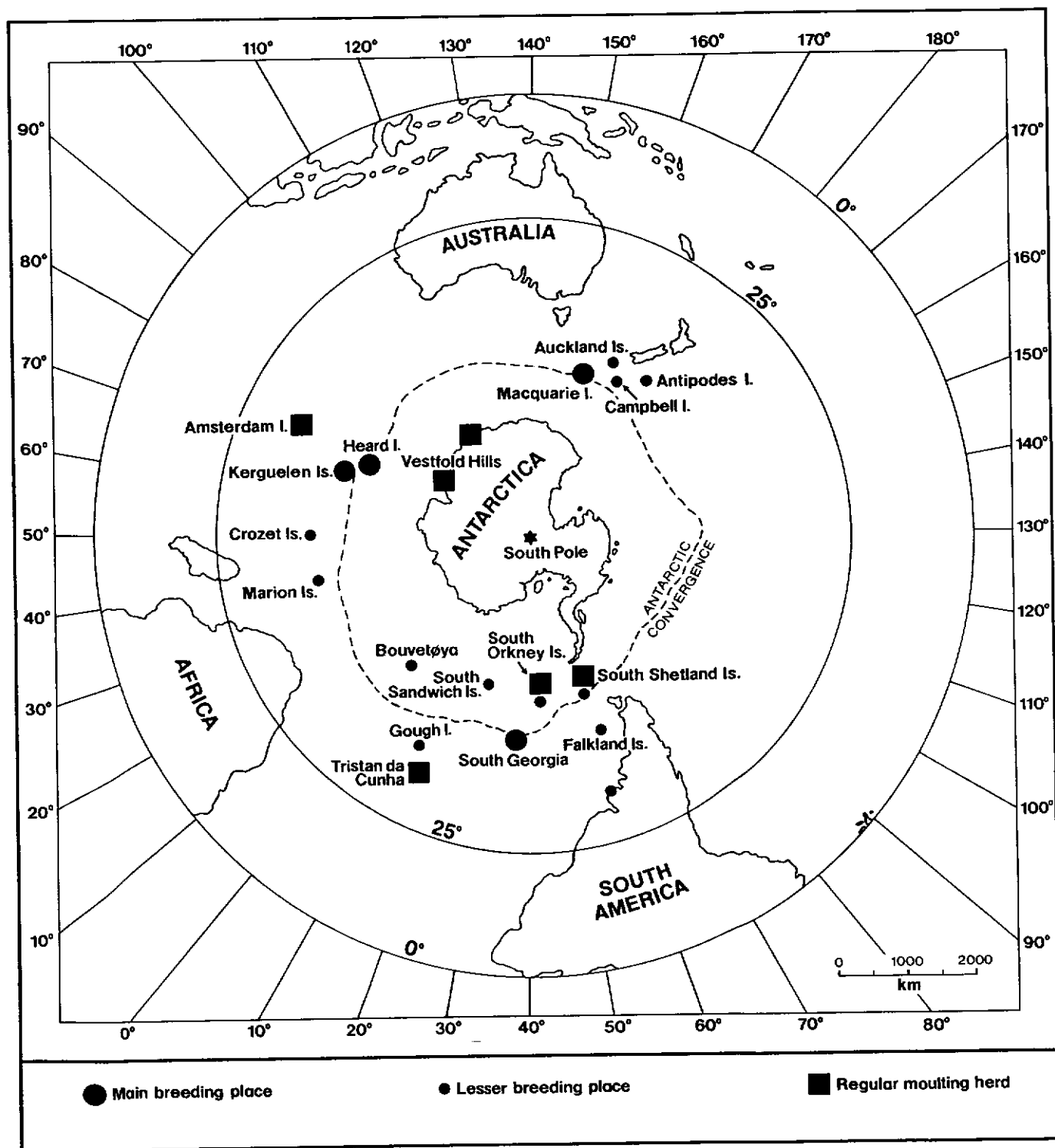


Fig. 9. The distribution of southern elephant seals in the Southern Ocean. The major breeding areas, on subantarctic islands in the southern Indian, Pacific and Atlantic Oceans, are shown as large circles.



△ Fig. 4. Antarctic krill *Euphausia superba*, length of adults 5–6 cm. (Photo: courtesy of Australian Antarctic Division.)



△ Fig. 5. Crabeater seals on floating pack ice. They inhabit the outer fringes of the pack. (Photo: courtesy of Australian Antarctic Division.)

▽ Fig. 6. Antarctic fur seals at South Georgia. (Photo courtesy of W. N. Bonner.)



▽ Fig. 10. A large harem of southern elephant seals at Macquarie Island. Breeding females and their pups form most of the aggregation; an adult male, very much larger than the females, is seen near the water.





Fig. 11a. Adult male elephant seal with a time-depth-temperature recorder and radio transmitter attached. The transmitter permits location of the animal when it returns to land, when the recorder can be retrieved. The device is shed at the next moult. (Photo: courtesy of Dr M. A. Hindell.)



Fig. 11b. Elephant seal being anaesthetized using syringe attached to remote injecting mechanism. The seal must be anaesthetized to attach time-depth-temperature recorder and radio transmitter.

Fig. 11c. Characteristic face of adult male elephant seal which gives the animal its name.



Fig. 16. Humpback whale cow and calf observed on aerial survey. They are readily seen from a height of 480 m.



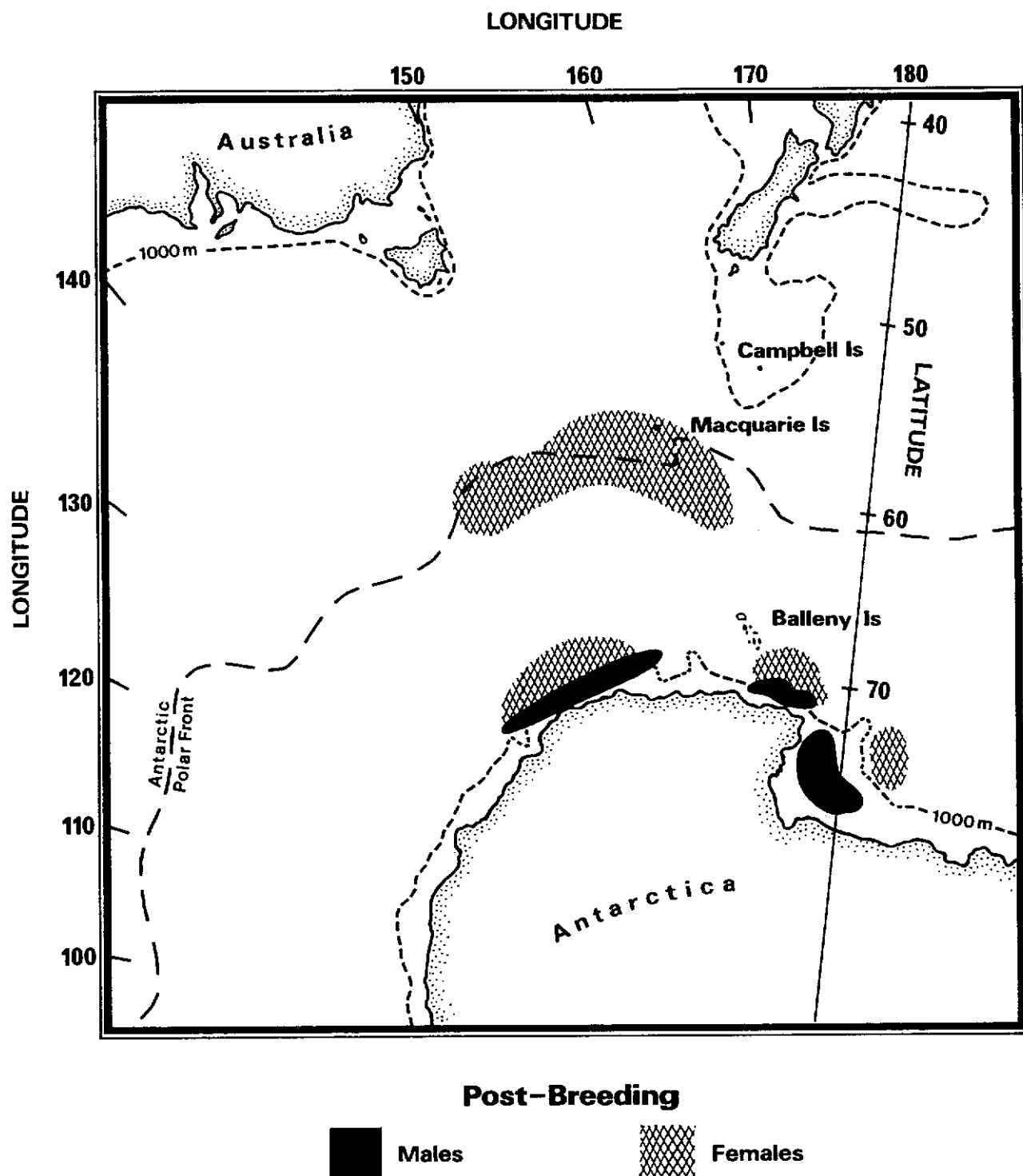


Fig. 12. Feeding areas of southern elephant seals that breed at Macquarie Island (from Hindell, Burton and Slip 1991).

Table 1. Total annual consumption of food and gross energy by southern elephant seals.

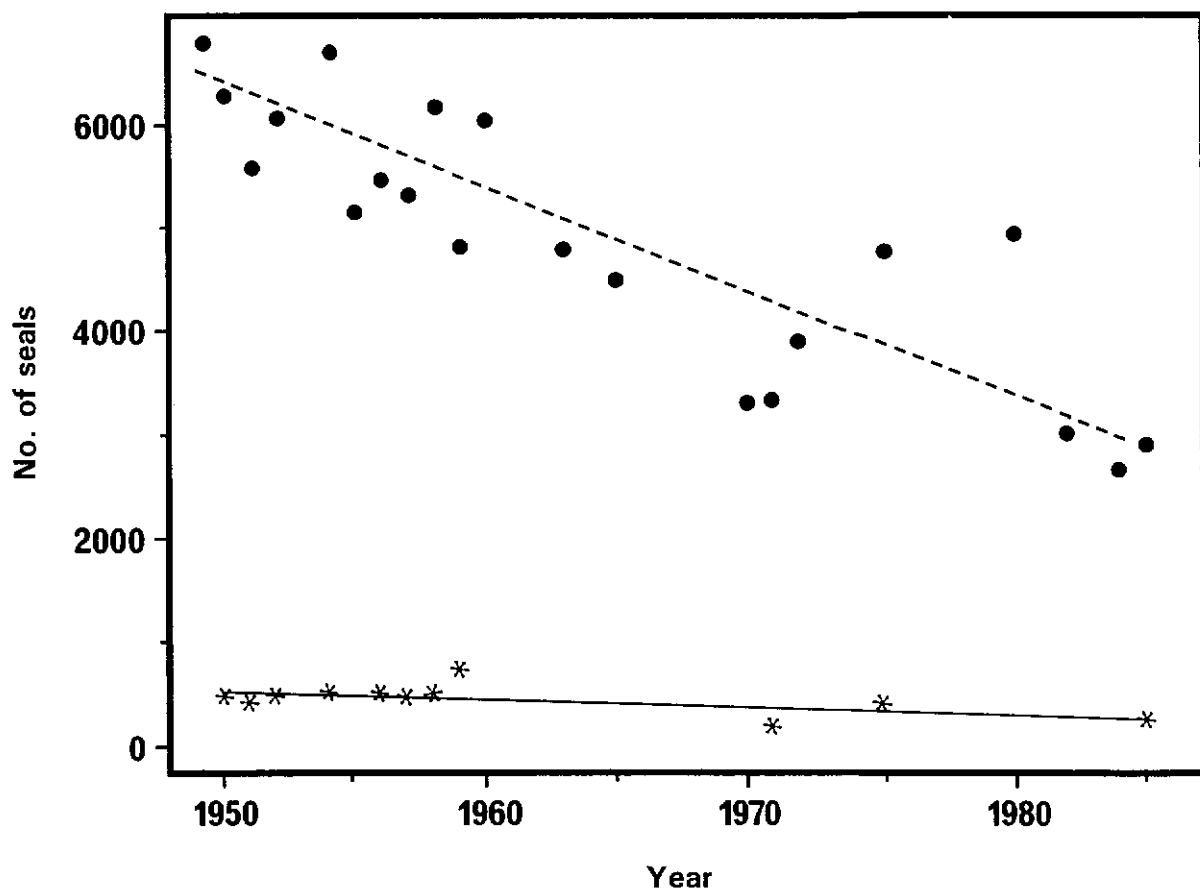
Source	Food consumed kg $\times 10^6$	Gross energy MJ $\times 10^9$
Naumov and Chekunova (1980)	3 800	32.6
Condy (1981)	2 971	—
Hindell (1990)	1 115	—
Krockenberger and Bryden (unpubl.)	3 045	21.0

the mid-1980s, but seems to be stabilising now (Fig. 13). Similar rates of decline occurred in the southern Indian Ocean population, but not in the southern Atlantic. Major fishing for squid and fin fish has occurred in the southern Atlantic, but not the Pacific and Indian Oceans, so the declines in elephant seal numbers cannot be attributed simply to reduction in food. Hindell discussed several possibilities in the Macquarie Island population, and concluded

that the decline may be a correction following an "overshoot" in the recovery of the population from extreme exploitation late last century and early this century. To my mind this is the most plausible argument, although others have been put forward. Whichever is correct, I believe it is fair to say that the declines are probably not simply food-derived. Because the reasons for the decline are not known with certainty, continued monitoring of populations of southern elephant seals, and intensive studies of their feeding and ranging patterns, are essential.

Humpback Whales

The second research project is centred on surveys of humpback whales on Australia's east coast. All southern rorquals feed in antarctic waters in the austral summer, and migrate north to tropical waters to breed in winter.



From: Hindell and Burton (1987)

Fig. 13. The decline in numbers of female (close circles) and male (asterisks) elephant seals at Macquarie Island from 1950 to 1985. The mean annual rate of decline is 2 per cent (after Hindell and Burton 1987).

Humpbacks have the convenient habit of following coastlines as they migrate, like the gray whales that migrate along the coastline of the west coast of the USA to and from Baja California. On Australia's east coast, they are particularly cooperative in that they remain very close inshore, at least in some parts of the coast, and like gray whales they can be counted from the shore. These humpback whales form a major part of what is known as Area V humpback stock (see Fig. 14).

The population was depleted severely in the period 1951–63, when shore-based whaling stations were operating at Byron Bay and Tangalooma. Some whales were also taken in antarctic waters in the summer months during the same period. The original population (in 1951) was estimated by Chittleborough (1965) to be approximately 10 000 whales. PhD. student Miranda Brown has been looking at the figures again, and there are suggestions that it may have been considerably more than that, even as high as 20 000. It was believed to be reduced to approximately 200 whales by 1963 (Chapman 1974). If these figures are correct, then this population was depleted to about 1 per cent of its original size by whaling.

Aerial surveys were conducted in the years 1980–82, during the northward migration, to determine the width of the migration corridor (Figs 15 and 16). It was estimated that whales can be seen up to 10 km from headlands in reasonable weather and sea state conditions, and that more than 95 per cent of all migrating whales were within visible distance of the shore. The positions of whale groups observed on aerial surveys are shown in Figure 17. More intensive aerial surveys off Point Lookout in 1991 revealed that all whales were within 10 km of the headland.

Indirect methods were used to determine the numbers of whales passing at night, and revealed that they are the same as those during the day. Assuming that all whales migrate, an estimate of the total number of whales passing the headland can be made. However, the estimates are minimum estimates, even though correction factors for weather and sea state, and observer error are applied. There is some evidence that some immature whales do not migrate, but the majority do.

The surveys have been carried out during the northward migration because:

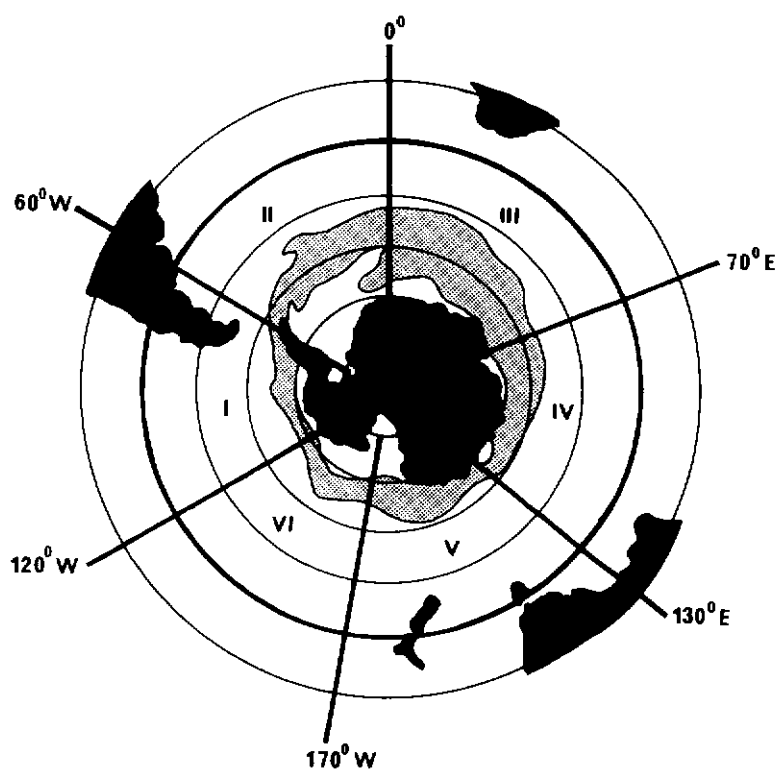


Fig. 14. The subdivision of the Southern Ocean into Areas I to VI, established for management of whaling by the International Whaling Commission. The areas do have some biological significance for humpback whales, in that the whales in some of the areas (III, IV and V, for instance) are separate populations, with limited interchange between them.

- (1) pod size is small. Whales migrate either alone or in pairs, occasional groups of three or four being seen. The maximum size of a group seen is five.
- (2) animals tend to move from south to north directly, with little diversion.

Northward migration past Point Lookout begins about mid May, and the vast majority of whales have passed by the end of August, the peak migration being reached about early July.

These surveys have shown that the population has increased rapidly in the 11 years since 1981. Up to now we have assumed the increase, peak and decline in daily counts describe a normal curve — see Figs 18–20. The appropriateness of this form of analysis was discussed by Bryden, Kirkwood and Slade (1990). Re-analysis is being considered at present. Using these methods, we have estimated that the average annual increase over the 11-year period 1981-91 has been of

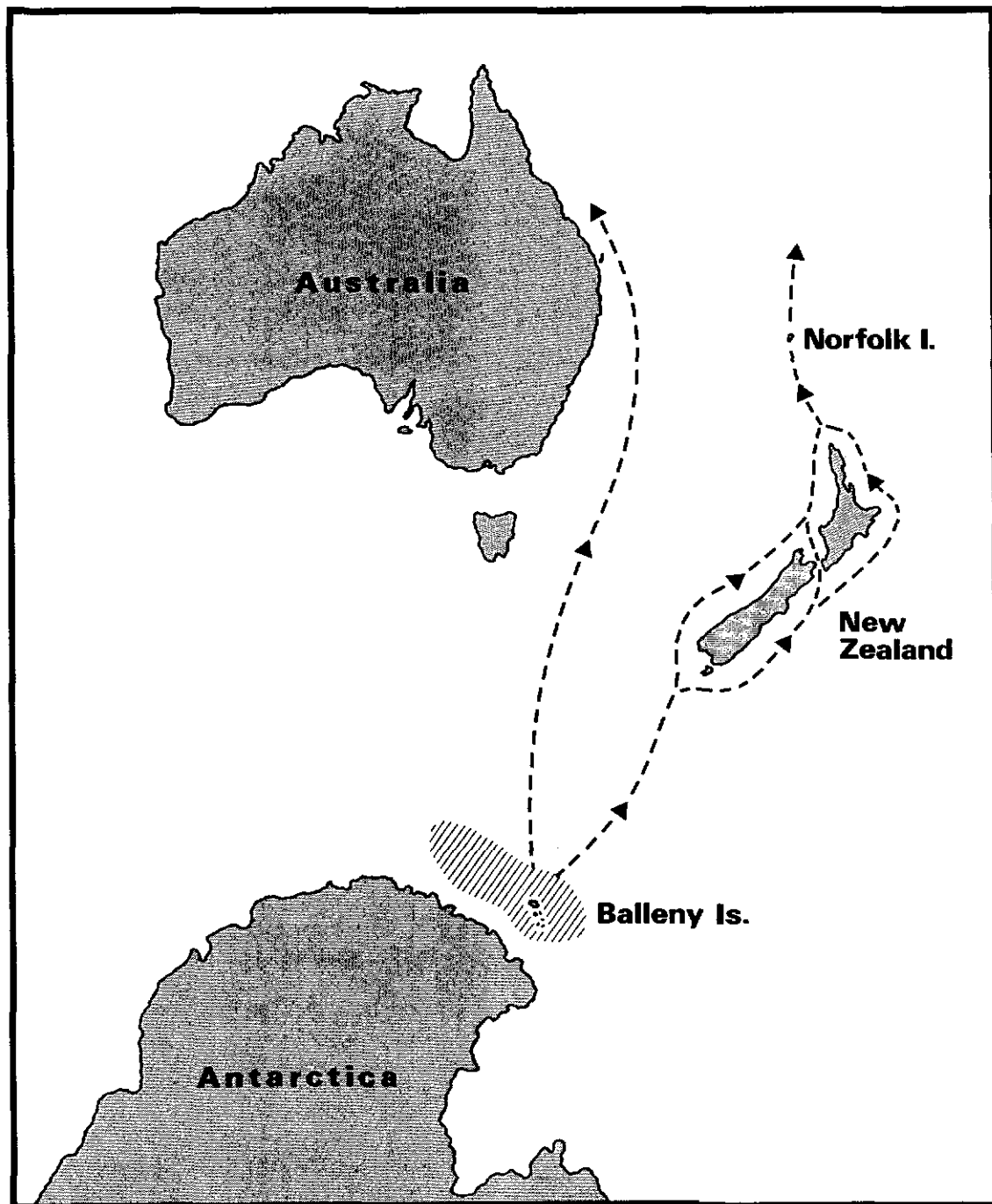


Fig. 15. The migration route of whales in Area V. The majority migrate between the east coast of Australia and Antarctica.

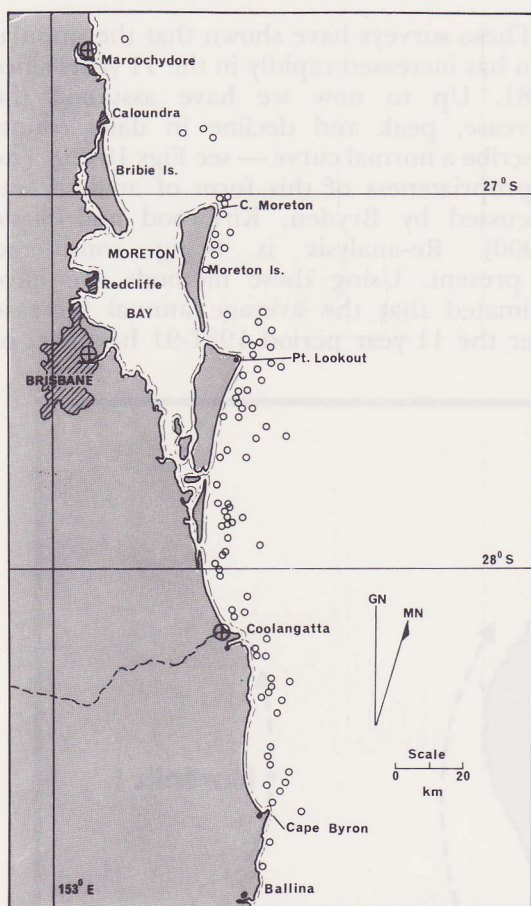


Fig. 17. Positions of humpback whale groups (pods) seen on aerial surveys, illustrating that in the region of Point Lookout on Australia's east coast, they migrate very close to shore.

the order of 13 per cent (Fig. 21). Although this seems to be very high, and caution has been expressed in assuming the figures are precise (Bryden *et al.* 1990), there is no doubt that the population is increasing at a high rate.

General Considerations

This year suggestions have come, mainly from commercial interests, that a cull of minke whales is necessary, to allow recovery of the endangered blue and fin whales. The argument goes, that minke whales have increased to such an extent that there is insufficient food for the larger rorquals. What is wrong with this argument?

- (1) The only species for which there are good population estimates for the Southern Ocean is the minke whale. The population is approximately 760 000 (IWC 1991), which may be greater than the number prior to southern whaling. The Scientific Committee of the International Whaling Commission has been unable to come up with good estimates of numbers of blue,

fin or sei whales, although a major effort to obtain reliable estimates is being made with the hope of obtaining them within two years.

- (2) No account is made of shifts in the populations of other krill predators, such as seals, sea birds, fish and large invertebrates.

Removal of significant numbers of minke whales, it could be argued, would result in even greater increases than have occurred already in other krill predators, such as crabeater seals, and fur seals, as well as birds, fishes and squid.

- (3) Although there are no reliable figures on total numbers of the larger rorquals, our humpback whale data indicate that these rorquals are doing very well, even though their numbers are still only 10 to 20 per cent of their pre-whaling levels.

Area IV humpback whales are also increasing, as revealed by John Bannister's aerial surveys, and studies of Area III, begun quite recently by Peter Best and students, indicate a recovery of humpbacks there.

Other rorquals, much more difficult to study, may be showing similar recovery.

Because they were depleted so severely their numbers, like those of humpback whales, will still be very low. Because of the difficulty of surveying them with the level of precision we have been able to achieve with the humpbacks, it may be many years before a significant recovery of the stocks of blue and fin whales can be recognized.

CONCLUSION

Although the Antarctic marine ecosystem is relatively simple compared to marine systems in other parts of the world, it is certainly more complex than it was believed to be 10 years ago. This has been illustrated by many studies of the lower trophic levels, and as I have pointed out, by the studies of elephant seals. The suggestion that culling a single species of krill predator will permit recovery of one or two others reveals either a high level of cynicism, or ignorance of the dynamics of marine ecosystems.

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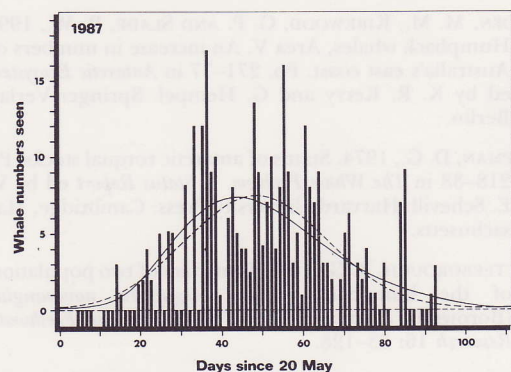
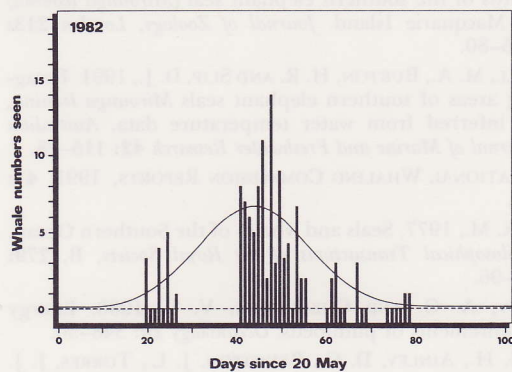
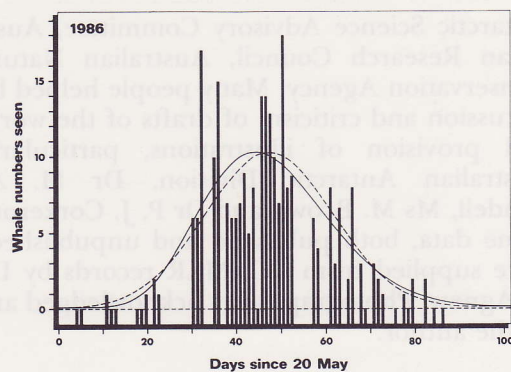
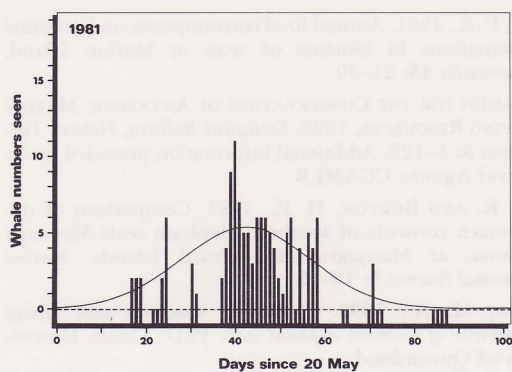


Fig. 18. Daily counts of humpback whales off Australia's east coast during the northward migration 1981-82, with estimated curves fitted (from Bryden, Kirkwood and Slade 1990).

Fig. 19. Daily counts of humpback whales (see Fig. 18) in 1986-87. Continuous line, normal distribution; dashed line, skewed distribution (from Bryden, Kirkwood and Slade 1990).

Daily counts of humpback whales - 1991

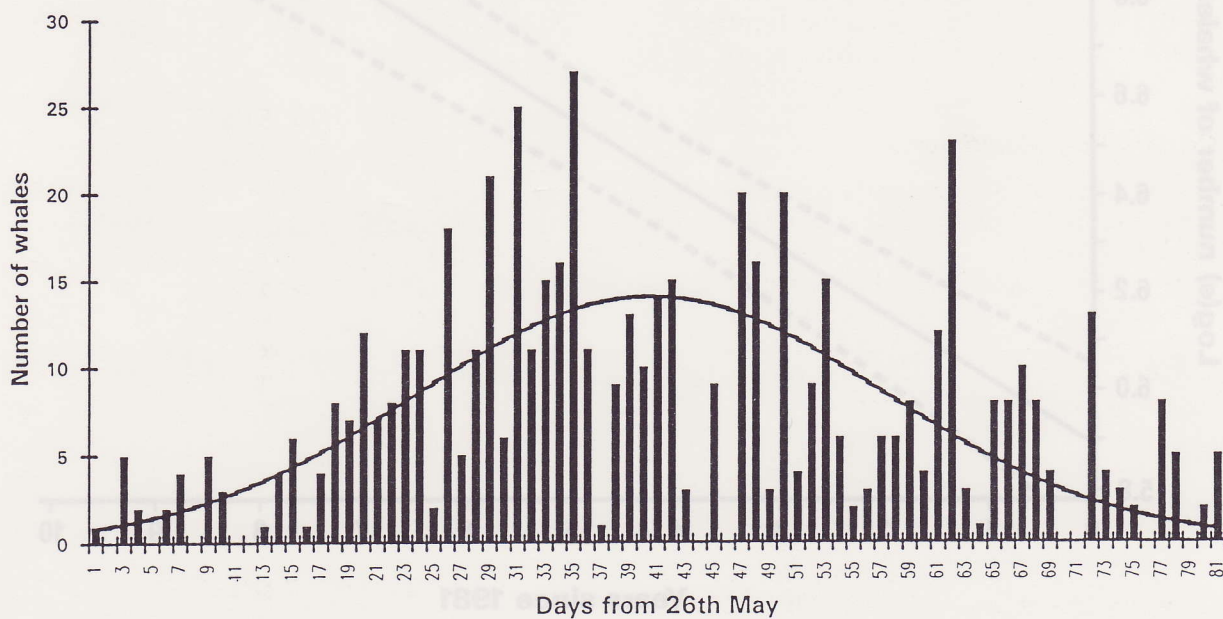
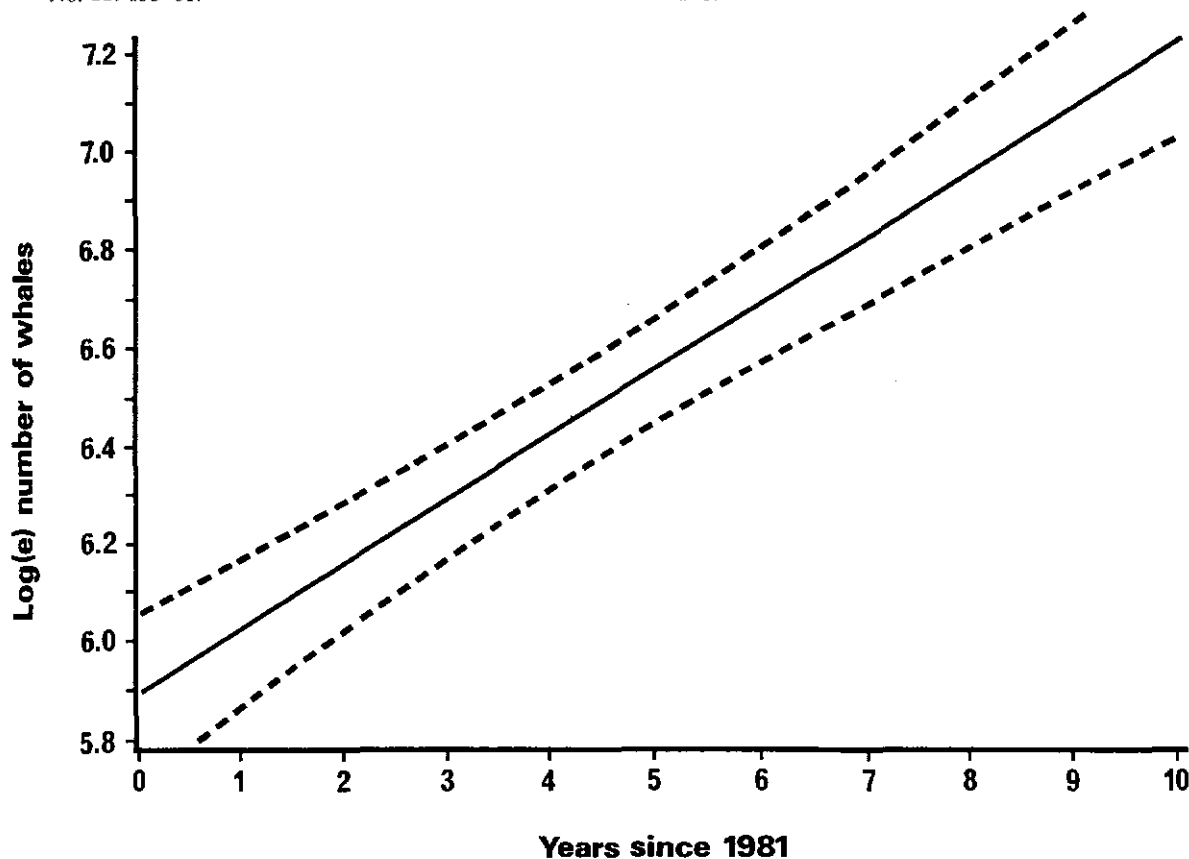


Fig. 20. Daily counts of humpback whales (see Fig. 18) in 1991.

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RATE OF INCREASE = 13.76%, $r = 0.99$, $p < 0.01$

Fig. 21. The estimated rate of increase of humpback whale numbers in eastern Australia from 1981 to 1991.